

Aligning regional and international biodiversity conventions to benefit butterfly conservation in Africa: A review

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Abstract

African butterflies play vital ecological roles but face numerous threats. Their protection requires aligning biodiversity conventions with butterfly-specific conservation goals. This review examines how to optimize regional and international conventions for enhanced African butterfly conservation. Through systematic assessment of relevant conventions, their provisions, success stories, and implementation effectiveness, I identify strategies to strengthen conservation outcomes. A comprehensive search of academic databases and official convention resources, using rigorous selection criteria, revealed that international frameworks support butterfly conservation through diverse mechanisms. The Convention on Biological Diversity (CBD) provides a foundational framework for biodiversity protection, including population monitoring and conservation. The African Convention on the Conservation of Nature and Natural Resources (ACCNNR) supports butterfly conservation indirectly through sustainable resource use and habitat protection. While climate change remains a significant threat, the UN Framework Convention on Climate Change (UNFCCC) offers mitigation tools. The Convention on International Trade in Endangered Species (CITES) regulates butterfly trade, with potential for greater impact through expanded species coverage and aligned strategies. The Ramsar Convention's wetland focus benefits butterflies when butterfly species are recognized as bioindicators in site management plans, while the World Heritage Convention protects critical habitats. Collectively, these conventions advance butterfly conservation through habitat protection, sustainable practices, awareness-raising, and international cooperation. However, their effectiveness is constrained by resource limitations and data deficiencies. To address these challenges, three key recommendations are proposed: (1) integrating butterfly-specific targets into national biodiversity strategies, (2) strengthening research capacity and enforcement mechanisms, and (3) creating a Pan-African conservation network for coordinated regional action. Additionally, promoting the use of butterflies as bioindicators in climate and land-use policies would simultaneously enhance conservation efforts and support broader ecosystem protection objectives.



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Introduction

African butterflies, particularly those in tropical forests and grasslands, play a critical role in healthy ecosystems (Edge and Mecenero 2015). As essential pollinators for diverse plant life (Taron and Ries 2015), they act as sensitive indicators of environmental changes, reflecting habitat degradation, pesticide use, and climate change (Ubach et al. 2022). Their importance extends beyond ecological health, supporting sustainable agriculture, ecotourism, and traditional knowledge (Pe'er and Settele 2008). To ensure their survival and the continued health of our environment, prioritizing habitat conservation and restoration, promoting sustainable land-use practices, and supporting butterfly research and public awareness are crucial to ensuring their survival (Taron and Ries 2015). International and regional conservation conventions play a vital role in supporting these efforts (Alvarado-Quesada and Weikard 2017). These conventions provide guidelines, resources, and platforms for cooperation, promoting habitat protection, regulating trade, fostering cross-border collaboration, and encouraging sustainable land-use practices (Chandra and Idrisova 2011). By setting conservation agendas, addressing threats, and facilitating scientific exchange, biodiversity conventions directly contribute to butterfly conservation in Africa (Trouwborst et al. 2017).

While international and regional biodiversity conventions offer a framework for African butterfly conservation, their effectiveness hinges on thorough review and better alignment of their objectives (Taron and Ries 2015; Trouwborst et al. 2017). Such review and alignment foster evidence-based decision-making for resource allocation (Trouwborst et al. 2017) and empower advocates to bridge policy gaps for stronger protections and funding (Chandra and Idrisova 2011). Furthermore, aligning local efforts with international goals strengthens their impact and aids conservation organizations in identifying funding mechanisms and raising awareness (Chandra and Idrisova 2011). By assessing implementation effectiveness and highlighting areas for improvement, this article empowers stakeholders to refine strategies, prioritize actions, and demonstrate the transformative power of international collaboration. A review and alignment of these conventions, therefore, presents a valuable tool for optimizing butterfly conservation efforts in Africa.

Review methodology

Search strategy

To comprehensively assess how regional and international biodiversity conventions can better support African butterfly conservation, this review employed a multi-pronged approach. First, a systematic search across prominent academic databases (ScienceDirect, Web of Science, and Google Scholar) was conducted using relevant keywords such as “butterfly conservation,” “biodiversity conventions,” and “Africa.” Second, the official websites of key biodiversity and conservation conventions (i.e., CBD, ACCNNR, UNFCCC, CITES, Ramsar Convention on Wetlands, the Basel Convention, and World Heritage Convention) were examined. This combined approach ensured a comprehensive review of both academic literature and official convention resources.

Selection criteria

To ensure high-quality information, this review employed strict selection criteria. Sources directly addressing butterfly decline, conservation strategies, and the role of biodiversity conventions were prioritized. Peer-reviewed publications from credible institutions and recent years were favored. Website content accuracy and affiliation with reputable organizations were also considered. Finally, sources aligned with biodiversity conventions, exploring their effectiveness and potential improvements for butterfly conservation in Africa, were chosen.

Overview of regional and international biodiversity conventions

Convention on Biological Diversity (CBD)

The Convention on Biological Diversity (CBD), adopted in 1992, serves as a global framework for the conservation and sustainable use of biodiversity, with its goals directly affecting efforts to protect African butterflies. Several key targets and goals within the CBD framework hold particular significance for butterfly conservation on the African continent (Convention on Biological Diversity 1992). Article 7 emphasizes the importance of identifying and monitoring biodiversity, crucial for understanding butterfly populations and their habitats. Articles 8 and 9 promote in situ and ex situ conservation, respectively, vital for protecting threatened butterfly species. Article 10 encourages the sustainable use of biological resources, including potential ecotourism opportunities related to butterfly watching. Article 12 emphasizes the importance of research and training, which can contribute to improved butterfly conservation strategies (CBD 1992). Article 13 highlights the need for public education and awareness, crucial for fostering public support for butterfly conservation. Article 14 emphasizes the need to assess and minimize the impacts of human activities on butterfly habitats. Articles 17 and 18 promote the exchange of information and international cooperation (CBD 1992), facilitating the sharing of knowledge and best practices in butterfly conservation across African countries.

The benefit of aligning these articles with butterfly conservation efforts in Africa is multifaceted. Firstly, it provides a strong legal and policy framework for integrating butterfly conservation into broader biodiversity conservation strategies. Secondly, it encourages the development of national and regional programs specifically focused on butterfly conservation. Thirdly, it facilitates international cooperation and knowledge sharing, enabling African countries to learn from each other and collaborate on effective conservation initiatives. Finally, it helps to raise public awareness about the importance of butterflies and their role in African ecosystems, fostering greater public support for conservation efforts.

African Convention on the Conservation of Nature and Natural Resources (ACCNNR)

The African Convention on the Conservation of Nature and Natural Resources (ACCNNR) offers a strong framework for butterfly conservation in Africa, even though butterflies are not its explicit focus. Similar to CBD, ACCNNR promotes sustainable use of resources (Article IV) to benefit future generations, including

butterflies (African Union, 1968). Healthy habitats are vital for butterflies, and ACCNNR's focus on soil and water conservation (Article V) indirectly supports their well-being (Jambhekar and Isvaran 2016). Article VI directly encourages measures for fauna and flora conservation, potentially including specific butterfly species. Furthermore, the establishment of protected areas under Article VII provides a framework for African nations to create safe habitats for butterflies. The Convention's guidance on national biodiversity policies can lead to stronger legal frameworks for butterfly conservation at the individual country level. Finally, public awareness and local community engagement, promoted by Article XVI, are crucial for successful butterfly conservation efforts across Africa (African Union 1968; Larsen 1995).

United Nations Framework Convention on Climate Change (UNFCCC)

Climate change profoundly impacts insect biology, significantly altering their life cycles, ecology, and conservation status (Moise 2011; Chandrakumara et al. 2023). Rising temperatures directly influence insect development, impacting growth rates, reproduction, and population dynamics. Rising temperatures, altered rainfall patterns, and increased frequency of extreme weather events directly impact butterfly populations and their host plants. These changes also exert significant physiological and behavioral impacts on butterflies, leading to reduced body size, impaired flight capabilities, and decreased reproductive success (Chandrakumara et al. 2023). Different life stages of insects exhibit varying sensitivities to temperature fluctuations, influencing their overall responses to climate change. Climate-induced shifts in distribution and phenology have been observed across numerous insect species, particularly within the order Lepidoptera (Moise 2011). These changes can lead to range expansions, increased overwintering survival, and an increase in the number of generations per year (Chandrakumara et al. 2023).

Furthermore, climate change significantly impacts intricate ecological interactions, including insect-plant relationships, predator-prey dynamics, and pheromonal communication (Chandrakumara et al. 2023). These combined effects can have cascading consequences, ultimately impacting the abundance and diversity of butterfly populations in Africa. The conservation of butterflies in Africa requires a multi-faceted approach that addresses the underlying drivers of climate change. The United Nations Framework Convention on Climate Change (UNFCCC) plays a crucial role in coordinating international efforts to mitigate climate change and its impacts. By promoting sustainable development practices, reducing greenhouse gas emissions, and enhancing climate resilience, the UNFCCC can help to protect butterfly populations and their habitats (United Nations Framework Convention on Climate Change 1992).

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) remains an essential tool for regulating the international butterfly trade and preventing species endangerment (Armstrong and Crawford 1998; Naess 2015). While only a limited number of African butterfly species currently receive CITES protection, the convention's framework for restricting trade in threatened taxa proves increasingly vital as new data reveal alarming trade volumes

(Convention on International Trade in Endangered Species of Wild Fauna and Flora 1973). Analysis of 50,555 online transactions (2020–2021) identified 3,767 traded species, seventeen times more than the 214 IUCN-recognized species, demonstrating an urgent need for expanded CITES listings (Wang et al. 2023).

This extensive trade, characterized by long-distance transport (averaging 4,814 km) from Global South source countries to Western buyers, with median prices (\$6.75/specimen) representing significant local economic value (Wang et al. 2023), underscores why CITES protections must be strengthened. The current situation, where most traded species lack monitoring or regulation, highlights CITES's critical role in (1) expanding species coverage, (2) improving traceability mechanisms, and (3) developing sustainable trade alternatives to protect both biodiversity and local livelihoods. Without such CITES interventions, this substantial but poorly monitored global trade network will continue threatening African butterfly populations.

Ramsar Convention on Wetlands

The Ramsar Convention, established in 1971, is the first international treaty dedicated to wetland conservation (Ramsar Convention on Wetlands 1971; Davidson 2016). While not directly focused on butterflies, it can indirectly benefit them through wetland protection. The convention promotes habitat conservation, encourages the development of management plans for wetlands, and emphasizes “wise use” practices that ensure sustainability (Ramsar Convention on Wetlands 1971). Importantly, the Ramsar Convention advocates for monitoring the ecological health of wetlands, which can include tracking butterfly populations as indicators of overall ecosystem well-being (Davidson 2016). This monitoring allows for early detection of broader environmental issues within the wetland and the implementation of corrective actions. To further align the Ramsar Convention with butterfly conservation in Africa, several key steps are crucial: explicitly recognizing butterfly species as valuable bioindicators within wetland ecosystems, highlighting their sensitivity to environmental change and their role in assessing wetland health; integrating butterfly conservation into management plans for Ramsar sites in Africa, including measures such as habitat restoration, minimizing disturbance, and promoting pollinator-friendly practices; encouraging and supporting (Ramsar Convention on Wetlands 1971) research on butterfly populations within Ramsar sites in Africa, contributing to a better understanding of their ecological roles, distribution, and conservation needs; and raising public awareness about the importance of wetlands for butterfly conservation and engaging local communities in wetland protection efforts. By incorporating these measures, the Ramsar Convention can significantly enhance its contribution to the conservation of butterflies and other biodiversity within African wetlands.

Basel convention on the control of transboundary movements of hazardous wastes and their disposal

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, while not explicitly focused on butterfly conservation, indirectly contributes to the protection of butterfly populations in Africa (The Basel Convention 1989). By prohibiting the illegal trade and improper disposal of hazardous wastes, such as industrial chemicals and agricultural

pesticides, the Convention helps to prevent the contamination of soil and water resources, thereby safeguarding crucial butterfly habitats. Furthermore, the Basel Convention promotes the sound management and disposal of hazardous waste, minimizing pollution and environmental degradation (The Basel Convention 1989). This pollution reduction can have a significant positive impact on butterfly populations by mitigating their exposure to harmful substances that can adversely affect their development, reproduction, and overall survival. Ultimately, by promoting sustainable waste management practices, including waste reduction, recycling, and environmentally sound disposal methods, the Basel Convention contributes to a healthier environment, creating more favorable conditions for the survival and thriving of butterfly populations in Africa.

World Heritage Convention

The World Heritage Convention, established in 1972, fosters international cooperation to safeguard cultural and natural treasures (UNESCO 1972). It aids developing countries with knowledge sharing, financial assistance, and coordinated efforts to combat threats like climate change and uncontrolled development (UNESCO 1972). This ensures the preservation and transmission of these invaluable assets for future generations. The convention prioritizes natural areas with exceptional universal value, including butterfly habitats in Africa (Fleishman and Murphy 2009; Deacon and Smeets 2013). It promotes biodiversity conservation, sustainable tourism practices, and public awareness of butterfly species. Additionally, the Convention encourages responsible land-use management to minimize negative impacts on ecosystems and butterflies (Deacon and Smeets 2013). By recognizing these exceptional sites, the convention elevates their importance for conservation (Fleishman and Murphy 2009; Deacon and Smeets 2013). Remarkably, several African World Heritage sites, like Virunga National Park (Democratic Republic of the Congo) and Bale Mountains National Park (Ethiopia), are crucial habitats for butterfly conservation.

The benefits of aligning biodiversity conventions for butterfly conservation

Butterflies are sensitive indicators of environmental health, and their populations are declining globally due to habitat loss, climate change, and unsustainable practices (Gravari-Barbas and Jacquot 2014). Africa, with high biodiversity, is generally less than that found in South America and Southeast Asia (Barlow et al. 2018) and is home to a stunning variety of butterfly species. However, many African butterflies face similar threats (Pomeroy 1993). To conserve these butterflies, a coordinated approach that aligns regional and international biodiversity conventions is crucial. Below is a breakdown of how the listed conventions contribute to butterfly conservation. Firstly, conventions help habitat protection and restoration programs. Habitat loss is a major threat to butterflies, fragmenting populations, disrupting their environment, and exposing them to dangers (Steffan-Dewenter and Tscharnkte 2000; Hanski 2011). This includes the loss of essential food sources, inadequate shelter and breeding sites, increased exposure to predators and parasites, heightened competition for resources, and the disruptive impact on their vital migration patterns.

Thus, conservation efforts focusing on protecting habitats and addressing the root causes of this loss help butterfly conservation (Dennis et al. 2006; Pullin 2012). International agreements promote habitat protection and restoration through creating protected areas, promoting sustainable land management, and fostering international cooperation. These conventions also encourage local community participation (Hanski 2011). Biodiversity conventions enhance local community participation by recognizing the role of indigenous knowledge, promoting equitable benefit-sharing, providing capacity-building support, decentralizing decision-making, and addressing drivers of biodiversity loss like poverty. These measures empower communities to engage in conservation efforts. However, challenges such as limited data, weak enforcement, insufficient funding, lack of awareness, and inadequate climate change considerations hinder effective butterfly conservation in Africa, threatening biodiversity (Dennis et al. 2006).

Second, conventions support species-specific conservation and management (SSCM) programs. SSCM adapts conservation efforts to each butterfly's needs (Chowdhury et al. 2023). It involves research on their life history, addressing specific threats, and monitoring populations (Habel et al. 2019). SSCM emphasizes efficient resource use and public engagement and serves as an indicator of overall ecosystem health (Thomas et al. 2010; Chowdhury et al. 2023). International agreements further support butterfly conservation by regulating trade and promoting cooperation for migratory species (Corn 2006). This targeted approach allows for effective interventions and maximizes the impact of conservation efforts. The SSCM offers several benefits for butterfly conservation, including increased effectiveness, targeted solutions to threats like habitat loss, climate change, disease, and over-collection, adaptive management, public awareness and engagement, and serving as ecological indicators (Gillespie 2013; Lewandowski and Oberhauser 2016). By focusing on specific butterfly species, SSCM ensures efficient resource use and successful interventions while also allowing for adjustments and improvements over time (Oberthür 2009).

Third, conventions can help research, public education, and collaboration for butterfly conservation in Africa (Von Bieberstein et al. 2019). They raise awareness and encourage collaboration through strategies, regional agreements, and support (Baakman 2011; Nummelin and Urho 2018). These networks connect stakeholders (Dongmo et al. 2023) and foster regional collaboration on education and conservation efforts (Baakman 2011; Von Bieberstein et al. 2019). A three-pronged strategy is essential for effective butterfly conservation in Africa, encompassing research, education, and collaboration (Stephenson et al. 2021). Research provides the foundation for informed conservation practices, while public education fosters broader support and citizen science engagement. Collaborative efforts optimize resource allocation and maximize conservation impact (Griffin and Ali 2014).

Fourth, conventions play a role in supporting environmental impact assessments (EIAs) and monitoring programs (Dongmo et al. 2023). Development projects pose significant threats to butterfly populations, making EIAs crucial tools for identifying and mitigating potential impacts (Morgan 2012). EIAs involve systematic planning, impact assessment, and the development of strategies to minimize harm to butterflies (Williams and Dupuy 2017). By fostering informed decision-making, these efforts contribute to the development of pathways that help protect butterfly populations, especially in Africa. Generally, biodiversity

conventions can effectively contribute to butterfly conservation by promoting habitat protection, species-specific conservation, research, education, collaboration, and environmental impact assessments. A comprehensive approach integrating these elements is crucial for the conservation of Africa's butterfly populations.

Success stories of biodiversity conventions in Africa

Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA)

KAZA TFCA, located in the Kavango and Zambezi River basins, is larger than Germany and Austria combined and nearly twice as large as the UK (Stoldt et al. 2020). It features the Okavango Delta and Victoria Falls. The Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA) is a vast transboundary protected area in southern Africa, spanning Angola, Botswana, Namibia, Zambia, and Zimbabwe (Stoldt et al. 2020). The vast KAZA TFCA offers an important haven for butterfly conservation. Established under the CBD and Ramsar Convention, this transboundary park protects diverse habitats, promotes butterfly movement through reduced fragmentation, and facilitates collaborative monitoring programs across member countries (UNESCO World Heritage Centre n.d.). Thus, international conventions play a pivotal role in advancing butterfly conservation. As exemplified by KAZA TFCA, these agreements facilitate large-scale conservation efforts. By fostering cooperation among nations, conventions enable the creation of expansive protected areas, such as the KAZA TFCA, which provide critical habitats for diverse butterfly species (KAZA TFCA Secretariat, n.d.). Moreover, these frameworks promote habitat connectivity, reducing fragmentation that can threaten butterfly populations. Collaborative monitoring programs, facilitated by conventions, enhance our understanding of butterfly distributions and trends, informing targeted conservation actions.

The Maloti-Drakensberg Transfrontier Conservation Area (MDTFCA)

The Maloti-Drakensberg Transfrontier Conservation Area (MDTFCA) exemplifies the success of transboundary collaboration in butterfly conservation (KZN Wildlife n.d.). Established under the CBD, this UNESCO World Heritage Site, spanning Lesotho and South Africa, safeguards a diverse mountain landscape highly important for numerous butterfly species (Zunckel 2012). The pronounced elevation changes within MDTFCA create a range of microclimates, supporting high-altitude specialists and valley-dwelling butterflies (Gorilla Agreement). Furthermore, the protected area is a vital refuge for the endemic butterfly species, ensuring their long-term survival by minimizing threats like overgrazing, invasive species, and habitat degradation (Gorilla Agreement). Collaborative monitoring programs facilitated by MDTFCA foster improved research and understanding of butterfly populations within this unique ecosystem.

Thus, international conventions are pivotal in fostering transboundary collaboration for butterfly conservation. The Maloti-Drakensberg Transfrontier Conservation Area (MDTFCA) serves as a prime example of this success. By spanning Lesotho and South Africa, it facilitates cross-border cooperation in conservation efforts, enabling the protection of migratory species and shared habitats. Moreover, the convention's framework supports collaborative research

and monitoring initiatives, enhancing our understanding of butterfly populations and informing effective conservation strategies within this unique region. By replicating the collaborative spirit, robust legal frameworks, and strong community engagement demonstrated in these case studies, butterfly conservation initiatives across Africa can significantly benefit. While challenges persist, the successes achieved in KAZA TFCA and MDTFCA underscore the transformative power of international cooperation in safeguarding African wildlife.

Challenges and gaps of biodiversity conventions for African butterfly conservation

While international biodiversity conventions offer a framework for conserving butterflies in Africa, significant challenges hinder their full effectiveness (Takang 2014; Geijzenborffer et al. 2017; Phang et al. 2020). Some of these challenges are listed in the following.

Implementation challenges

Many African countries lack the financial and human resources for the effective implementation of convention provisions (Dirzo and Raven 2003; Birhanu 2010; Botchway and Hlovor 2019). This can hinder their ability to conduct thorough research, establish protected areas, or implement conservation programs. Thus, the most important is capacity building (Phang et al. 2020). However, building the capacity of local governments and communities to manage butterfly conservation programs effectively can be challenging. Monitoring the effectiveness of conservation efforts and enforcing regulations to protect butterflies can be difficult, especially in vast and resource-limited African landscapes (Geng et al. 2023).

Limitation of butterfly-specific focus

Biodiversity conventions present a double-edged sword for butterfly conservation in Africa. On the positive side, they indirectly protect habitats, raise awareness, integrate butterfly conservation into national plans, and provide funding. However, they often lack a species-specific focus, have limited resources, and compete for attention with other conservation priorities. While conventions encourage holistic national biodiversity strategies, there is a need for more targeted plans for critically endangered African butterflies. Translating broad goals into actions requires additional focus and resources within African nations. Furthermore, conventions lack specific action plans for individual species. To maximize effectiveness, butterfly conservation can be integrated into National Biodiversity Strategies and Action Plans (NBSAPs) (Phang et al. 2020). Raising awareness about butterflies' ecological importance and developing targeted strategies within broader plans can create a holistic approach benefiting all species.

Gaps in addressing specific threats

Habitat loss and degradation in Africa, particularly to butterflies, is a major threat to biodiversity (Ayyad 2003). Factors include land-use change, unsustainable resource extraction, climate change, and invasive species (Maitima et

al. 2009). Conventions often lack enforcement mechanisms to prevent habitat loss, and climate change impacts butterfly populations as degradation disrupts breeding grounds, food plants, movement patterns, genetic diversity, and microclimate (Maitima et al. 2009; Mohammed 2020). Effective communication, stronger regional collaboration, and knowledge sharing between African nations, researchers, and NGOs involved in butterfly conservation can be hampered by logistical and financial constraints (Mabudafhasi 2002).

Data deficiencies on butterflies

Limited data on African butterfly diversity and populations hinder conservation efforts (Xing et al. 2019). Monitoring vast areas is challenging due to resource constraints (Zerbe 2005). This lack of knowledge makes it difficult to prioritize species for conservation or measure success (Girardello et al. 2019). Bridging these knowledge gaps requires investment in research, long-term monitoring programs, collaboration, and standardized data collection methods. A stronger understanding of butterfly ecology is essential for effective conservation strategies (Hochkirch et al. 2020).

Conclusion and future recommendations

Conclusion

International biodiversity conventions form the backbone of butterfly conservation strategies in Africa. These conventions, including the Ramsar Convention, World Heritage Convention, CBD, and CITES, provide a framework for collaboration, resource sharing, and best practices. They promote habitat protection, sustainable land management, and the development of species-specific conservation plans for butterflies. While some conventions like Ramsar and UNFCCC indirectly benefit butterflies through wetland and climate change mitigation efforts, others like CBD and CITES have a more direct impact by focusing on species-specific conservation and trade regulation. The true strength lies in aligning these international frameworks with national implementation strategies. Challenges like weak enforcement and limited resources can be addressed by prioritizing butterflies in national biodiversity plans, developing targeted action plans, and investing in research and capacity building. Strengthening regional cooperation and fostering community engagement are also crucial for effective on-the-ground action. By bridging the gap between international goals and national implementation, African nations can harness the power of these conventions to secure a brighter future for their magnificent butterfly populations.

Future recommendations

To maximize the impact of international biodiversity conventions on African butterfly conservation, the following strategies should be prioritized. First, national policies need to explicitly incorporate butterfly-specific targets by integrating them into National Biodiversity Strategies and Action Plans (NBSAPs). This should include designating critical butterfly habitats (such as wetlands under the Ramsar Convention) and listing threatened species under CITES.

Second, enhancing research and monitoring capacity is essential to address existing data gaps. Standardized, long-term monitoring programs aligned with CBD on identification and monitoring should be established. Regional collaborations and funding mechanisms under conventions like the UNFCCC should be leveraged to support climate-resilience studies for migratory butterfly species. Third, strengthening enforcement and community engagement is critical for effective conservation. CITES enforcement efforts must be strengthened by training customs officials to identify and intercept high-risk species, thereby supporting local livelihoods and habitat protection. Fourth, fostering regional collaboration through a Pan-African Butterfly Conservation Network would help harmonize monitoring protocols, share best practices, and advocate for stronger alignment of international conventions. Finally, butterflies must be explicitly included in climate and land-use policies as key bioindicators. Their inclusion in UNFCCC National Adaptation Plans (NAPs) and Ramsar site management strategies would highlight their ecological significance while promoting integrated conservation efforts. By implementing these strategies, international biodiversity conventions can be more effectively aligned to address the unique conservation challenges facing African butterflies, ensuring their preservation for future generations.

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Data availability

All of the data that support the findings of this study are available in the main text.

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